where R is hydrogen or lower alkyl,

wherein said chiral centers are connected by a direct bond or by a chain of one to three atoms comprising linkages selected from alkyl (carbon-carbon), alkyl ether (carbon-oxygen), alkyl amino (carbon-nitrogen), or a combination thereof,

and, linked to each said group X,

(ii) a heteroaryl binding group Cy_N having a ring nitrogen atom effective to bind to a metal atom selected from the group consisting of molybdenum, tungsten, and chromium,

wherein said binding group is linked to said group X at a ring carbon adjacent to said ring nitrogen atom, is optionally substituted with one or more groups selected from alkyl, alkenyl, aryl, aralkyl, alkoxy, aryloxy, acyl, acyloxy, amide, tertiary amine, nitro, or halogen, and may be fused to one or more additional rings,

with

(b) a hexacoordinate complex of a metal selected from tungsten(0), chromium(0), and molybdenum(0),

whereby said complex undergoes a ligand exchange reaction, such that L^1 becomes coordinated to said metal;

wherein said composition is effective to catalyze the enantioselective alkylation of an allyl group bearing a leaving group at its allylic position.

18. The composition of claim 17, wherein in said process said metal is molybdenum (0).

19. The composition of claim 17, wherein in said process said hexacoordinate complex comprises ligands selected from the group consisting of CO, cycloheptatriene, lower alkyl nitrile, and lower alkyl isonitrile.

20. The composition of claim 17, wherein said first and second chiral centers are further substituted with groups R^1 and R^2, respectively,

wherein R^1 and R^2 are independently selected from aryl, heteroaryl, aralkyl, carbocycle, or heterocycle, and are optionally substituted with one or more groups selected from alkyl, alkenyl, aryl, aralkyl, alkoxy, aryloxy, acyl, acyloxy, amide, tertiary amine, nitro, or halogen, or

R^1 and R^2 together form a carbocyclic or heterocyclic ring, which is optionally substituted with one or more groups selected from alkyl, alkenyl, aryl, aralkyl, alkoxy, aryloxy, acyl, acyloxy, amide, tertiary amine, nitro, or halogen, and which may be fused to one or more additional rings.

21. The composition of claim 20, wherein said chiral centers are connected by a direct bond, and

said chiral component is thereby derived from a chiral 1,2-diol, -diamine, or -amino alcohol.

54. (Twice Amended) The composition of claim 20, wherein said ligand L_1 has the structure

$$Cy_N–(C=O)–X–C^*R^1R^3–C^*R^2R^4–X–(C=O)–Cy_N$$

wherein said chiral centers are connected by a direct bond, R^1 and R^2 are as defined above, R^3 and R^4 are hydrogen, and binding groups Cy_N are as defined above.

55. (Twice Amended) A catalytic organometallic composition, wherein the composition is the product of a process which comprises

contacting, in a nonprotic, noncomplexing solvent, a chiral ligand L^1 comprising:

(a) an axially chiral 1,1'-binaphthyl system, said system substituted at its 2 position and at its 2' position with a group X selected from -O- or -NR-, where R is hydrogen or lower alkyl, and, linked to each said group X,

(ii) a heteroaryl binding group Cy_N having a ring nitrogen atom effective to bind to a metal atom selected from the group consisting of molybdenum, tungsten, and chromium,

wherein said binding group is linked to said group X at a ring carbon adjacent to said ring nitrogen atom, is optionally substituted with one or more groups selected from alkyl, alkenyl, aryl, aralkyl, alkoxy, aryloxy, acyl, acyloxy, amide, tertiary amine, nitro, or halogen, and may be fused to one or more additional rings;

with a hexacoordinate complex of a metal selected from tungsten (0), chromium (0), and molybdenum(0),

whereby said complex undergoes a ligand exchange reaction, such that L^1 becomes coordinated to said metal;

wherein said composition is effective to catalyze the enantioselective alkylation of an allyl group bearing a leaving group at its allylic position.

56. (Amended) The composition of claim 55, wherein in said process said metal is molybdenum (0).

57. The composition of claim 17, wherein said solvent is selected from the group consisting of ethers, hydrocarbon solvents, and mixtures thereof.

58. (Amended) The composition of claim 57, wherein said solvent is selected from the group consisting of THF, toluene, and mixtures thereof.